May 9 - 13
Edinburgh, Scotland

Fuel Tank Vulnerability to Shaped Charge Jet

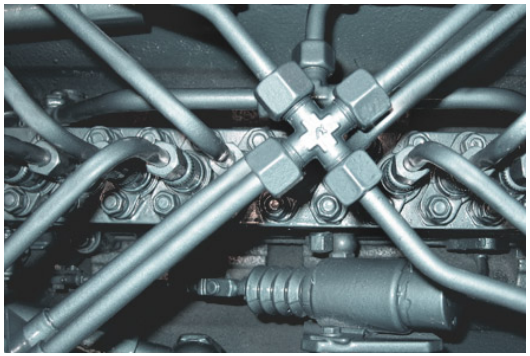
T. Hartmann, E. Rottenkolber, W. Arnold and O.M. Moon

TDW an MBDA company

NUMERICS

Introduction

Flamable liquids like fuel and hydraulic oil can be found aboard all armord comabt vehicles



Introduction

Combustion and / or burning of these liquids in a shaped charge attack significantly increases losses(*)

→ inhibiting or mitigating combustion and sustained fires would increase survivability and chance for repair

(*) Wright, B.R. and W.D. Weatherford. 1980. “Investigation of Fire-Vulnerability-Reduction Effectiveness of Fire-Resistant Diesel Fuel in Armored Vehicular Fuel Tanks”, AFLRL-Report No. 130, U.S. Army Fuel and Lubricants Research Laboratory, Southwest Research Institute, San Antonio, Texas

Introduction

Various passive inerting systems have been developed for aircraft fuel tanks

But: not applicable to ground vehicles

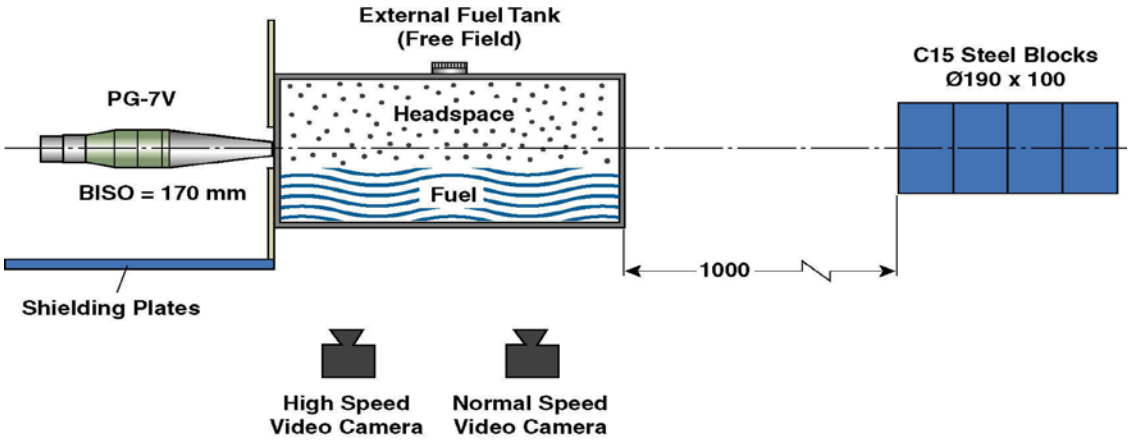
→ tests in literature mainly focus on fast-reacting fire extinguishing systems (FES) and on fire-resistant fuels (FRF)

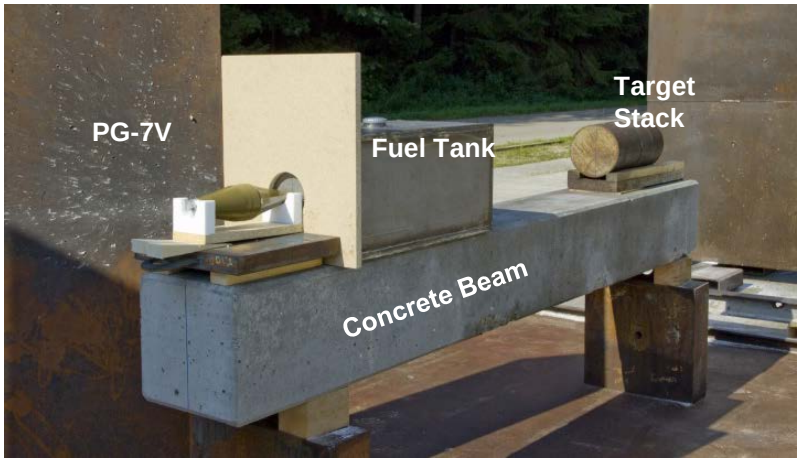
→ details on the ignition of flamable liquids during or after a shaped charge jet penetration has hardly been investigated / documented in open literature

➔ **To obtain more insight into the processes involved and to identify influencing factors, additional tests were required**

Experiments

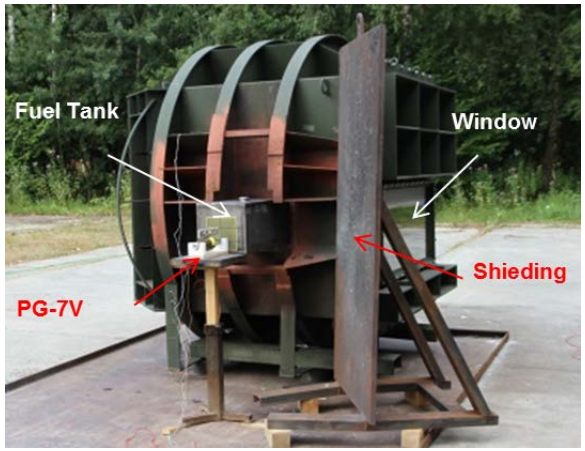
Two types of tests were conducted: free-field tests and pressure vessel tests

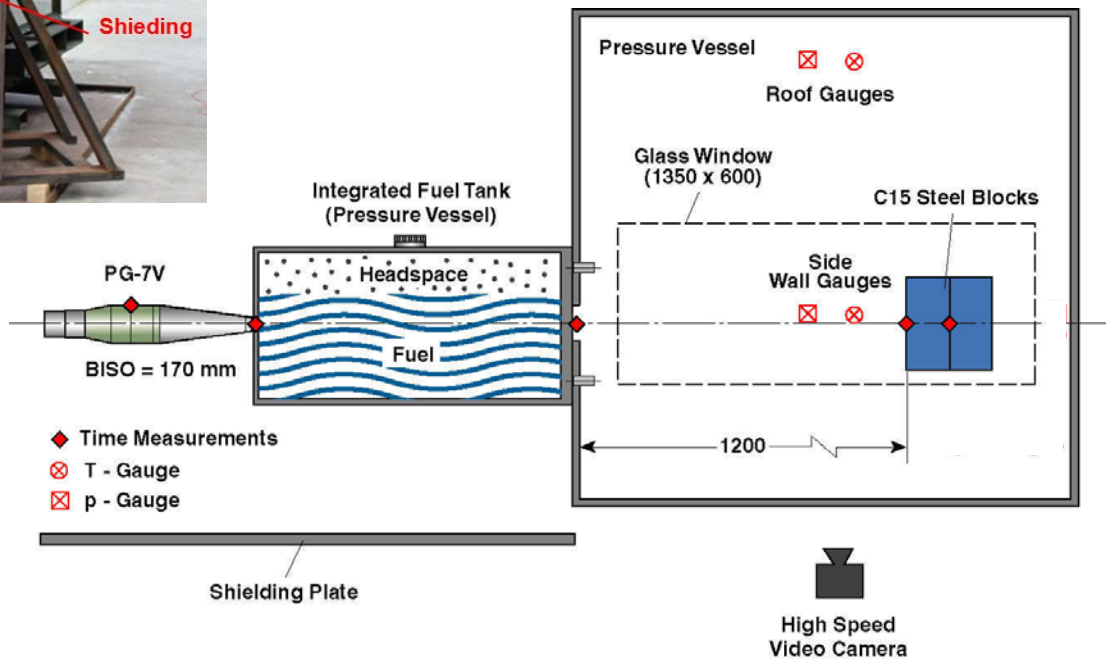




Experiments

Two types of tests were conducted: free-field tests and pressure vessel tests





Experiments

Types of fuel investigated: diesel (F54)
kerosene (JP8)

+ variation of filling level and impact point

Test No.	Setup	Fuel Type	Filling Level	Impact Point
HL56171	free field	diesel	50%	middle
HL56172		diesel	95%	middle
HL56173		kerosene	50%	bottom
HL56174		kerosene	50%	top
HL56175	pressure vessel	kerosene	50%	top
HL56176		kerosene	50%	bottom
HL56177		diesel	50%	top
HL56178		diesel	50%	bottom

Experiments

Test No.	Setup	Fuel Type	Filling Level	Impact Point
HL56171	free field	diesel	50%	middle
HL56172		diesel	95%	middle
HL56173		kerosene	50%	bottom
HL56174		kerosene	50%	top
HL56175	pressure vessel	kerosene	50%	top
HL56176		kerosene	50%	bottom
HL56177		diesel	50%	top
HL56178		diesel	50%	bottom

Driving questions:

- What are the effects leading to an ignition of the fuel spray?
- Does the impact point on the tank (ullage / liquid column) play a role?
- Are there differences in ignition / combustion of diesel and kerosene?
- Under which circumstances is a persistent fire likely to occur?

Free Field Tests

Exemplary normal speed video of test HL56171 (diesel; impact on surface level)

Free Field Tests

Exemplary high speed video of test HL56171 (diesel; impact on surface level)

→ instantaneous combustion of the fuel around the jet

→ no igition / combustion of fuel ejected behind the jet

Free Field Tests

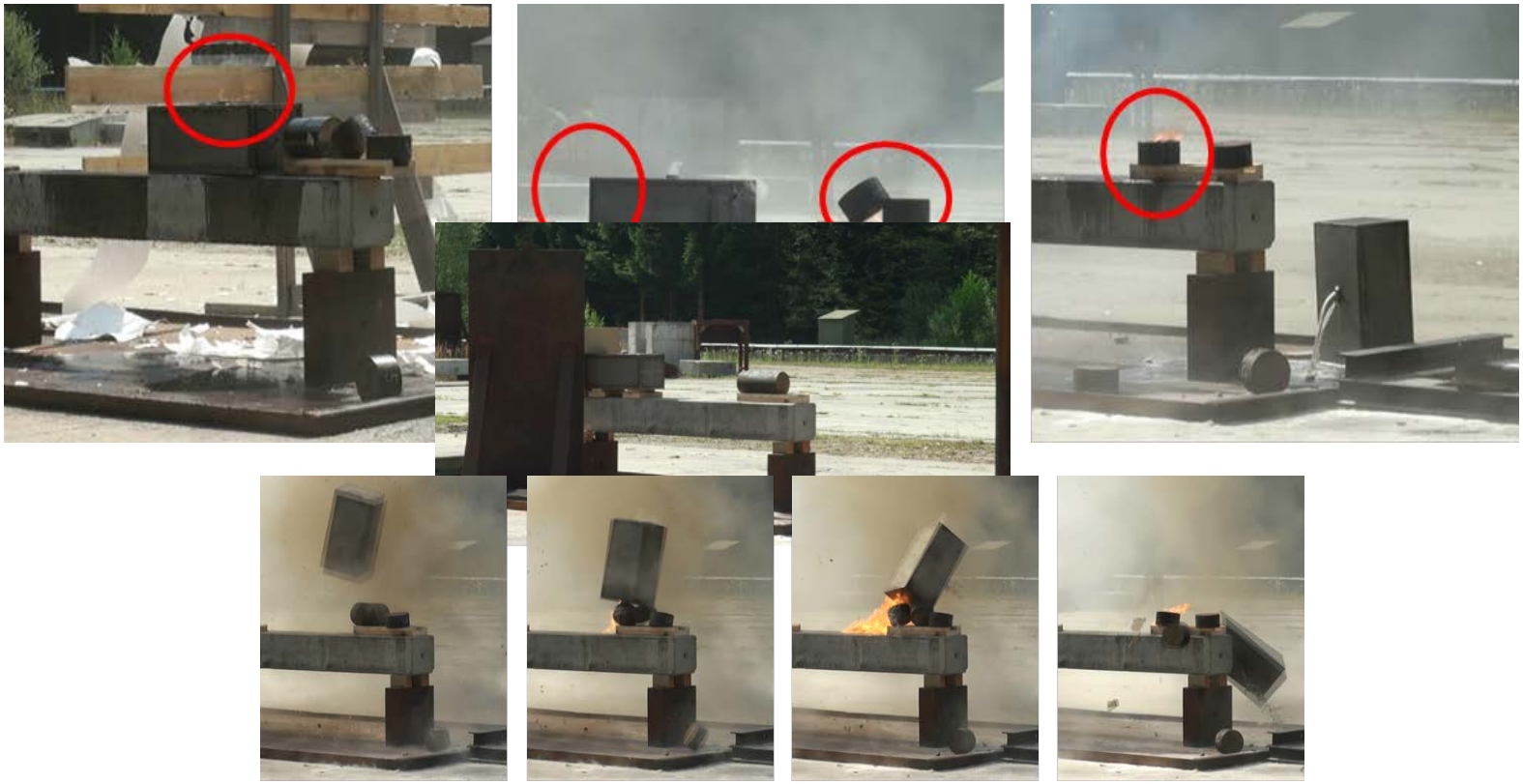
Specific observations in test HL56174 (kerosene, impact in ullage)

→ second combustion event inside target stack

→ only observed in shot through ullage

Free Field Tests

Location of sustained fires

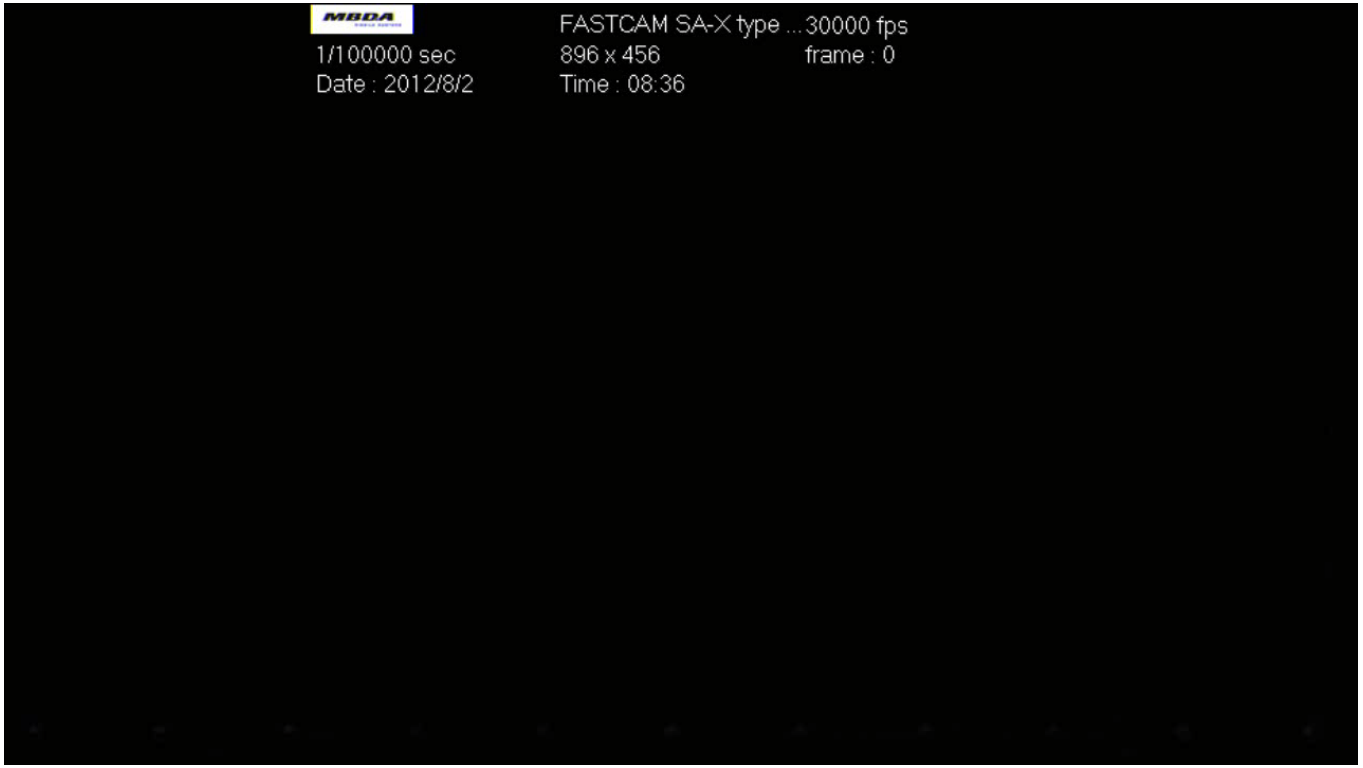


→ Practically no pool fires and no spreading

→ Sustained fires limited to hot surfaces

Pressure Vessel Tests

Exemplary high speed video of test HL56176 (kerosene; impact in liquid column)



→ instantaneous combustion of the fuel around the jet

→ no igition / combustion of fuel ejected behind the jet

➔ **no significant differences to free field tests**

Pressure Vessel Tests

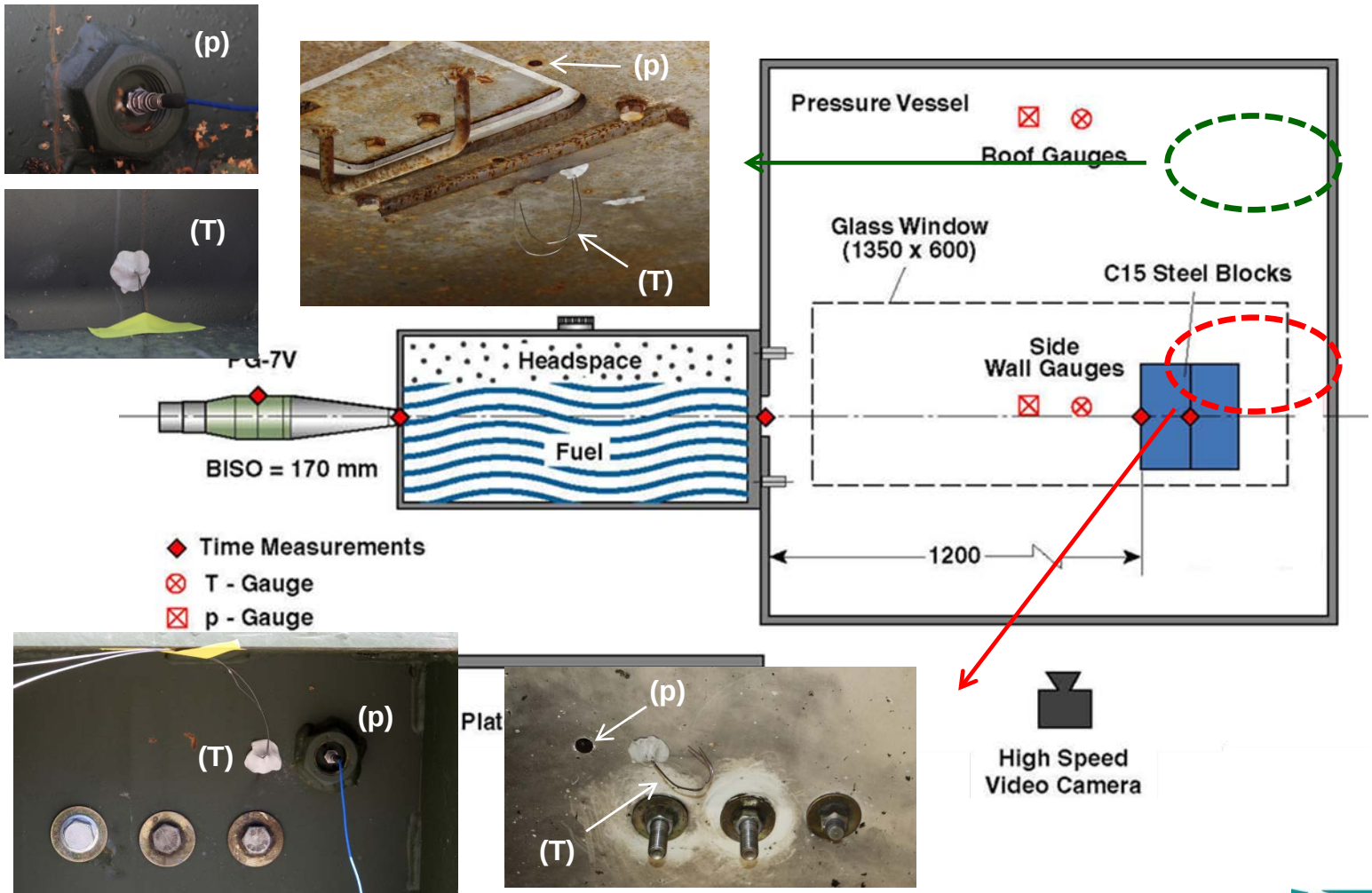
Specific observations in test HL56175 (kerosene, impact in ullage)

→ second combustion event inside target stack

→ again observed in both shots through ullage

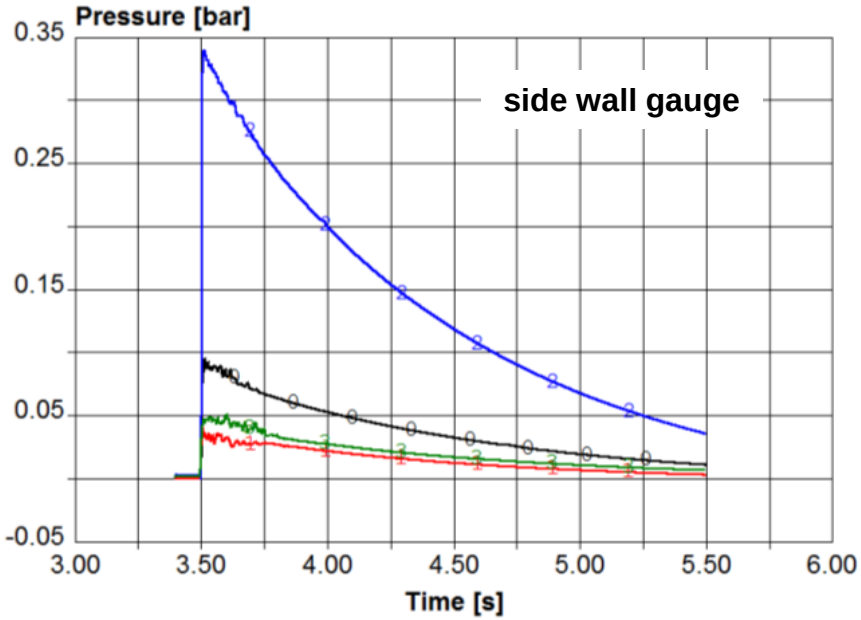
Pressure Vessel Tests – Data Measurements

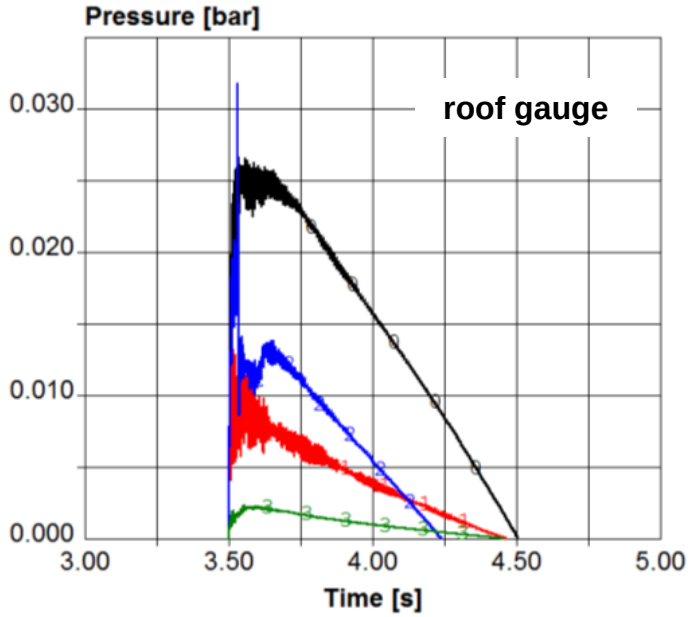
Gauge positions and mounting



Pressure Vessel Tests – Pressure Recordings

p-t histories recoded at the two gauge positions



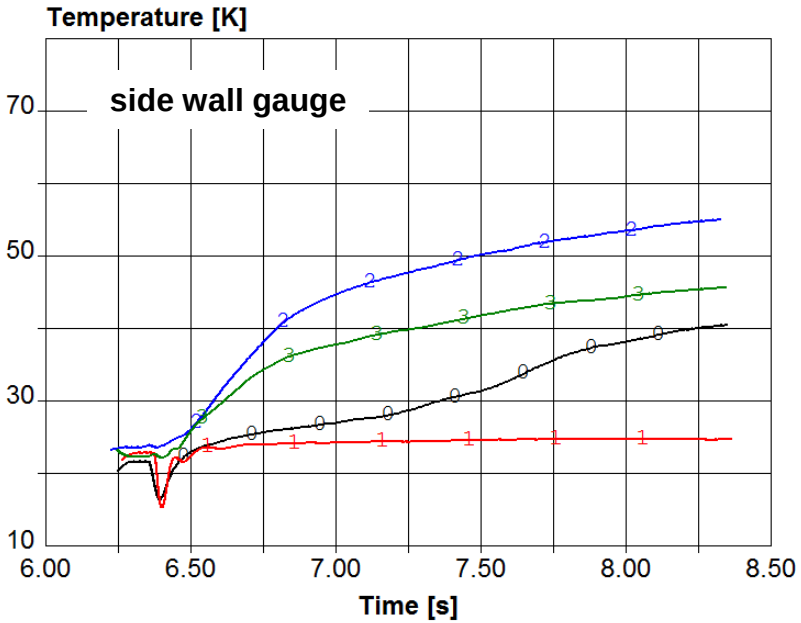


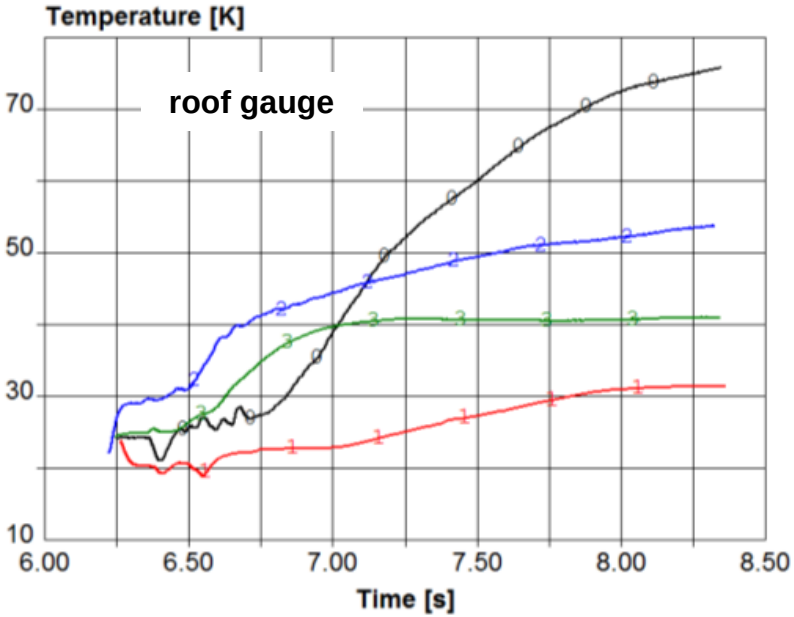
0 = HL56175 - kerosene, ullage
1 = HL56176 - kerosene, liquid
2 = HL56177 - diesel, ullage
3 = HL56178 - diesel, liquid

- → Qualitatively and quantitatively unexpected result from roof gauge
- → higher pressure produced by diesel
- → higher pressure when SC strikes the ullage

Pressure Vessel Tests – Temperature Recordings

T-t histories recoded at the two gauge positions





0 = HL56175 - kerosene, ullage
1 = HL56176 - kerosene, liquid
2 = HL56177 - diesel, ullage
3 = HL56178 - diesel, liquid

- → radiant heat and fire ball not captured
- → equilibrium temperature not fully reached
- → results not totally conclusive

Conclusion

- PG-7V shaped charges were fired on stand-alone fuel tanks and fuel tanks mounted to a pressure vessel
- All experiments exhibited instantaneous combustion of fuel around the jet upon exiting the tank, probably igited by the hot jet / target fragments.
  → combustion of flamable liquids will always occur in SC attack
  → spacing between tank and compartment might mitigate combustion effects
- Fuel ejected from the tank behind the jet was not ignited – even with strong mixing with air due to shock reverberation inside the pressure vessel.
- A second combustion inside the target stack could be observed in all shots through the ullage (practical relevance of this finding seems questionable).
- Sustained (pool) fires could only be observed on hot surfaces.
  → fuel and surface temperature seem to be a crucial factor
- Pressure and temperature recordings were only partly conclusive.
  → differences between diesel and kerosene cannot be explained based on physical or chemical properties
  → intensity of combustion may not be fully deterministic

Thank You for Your Attention !